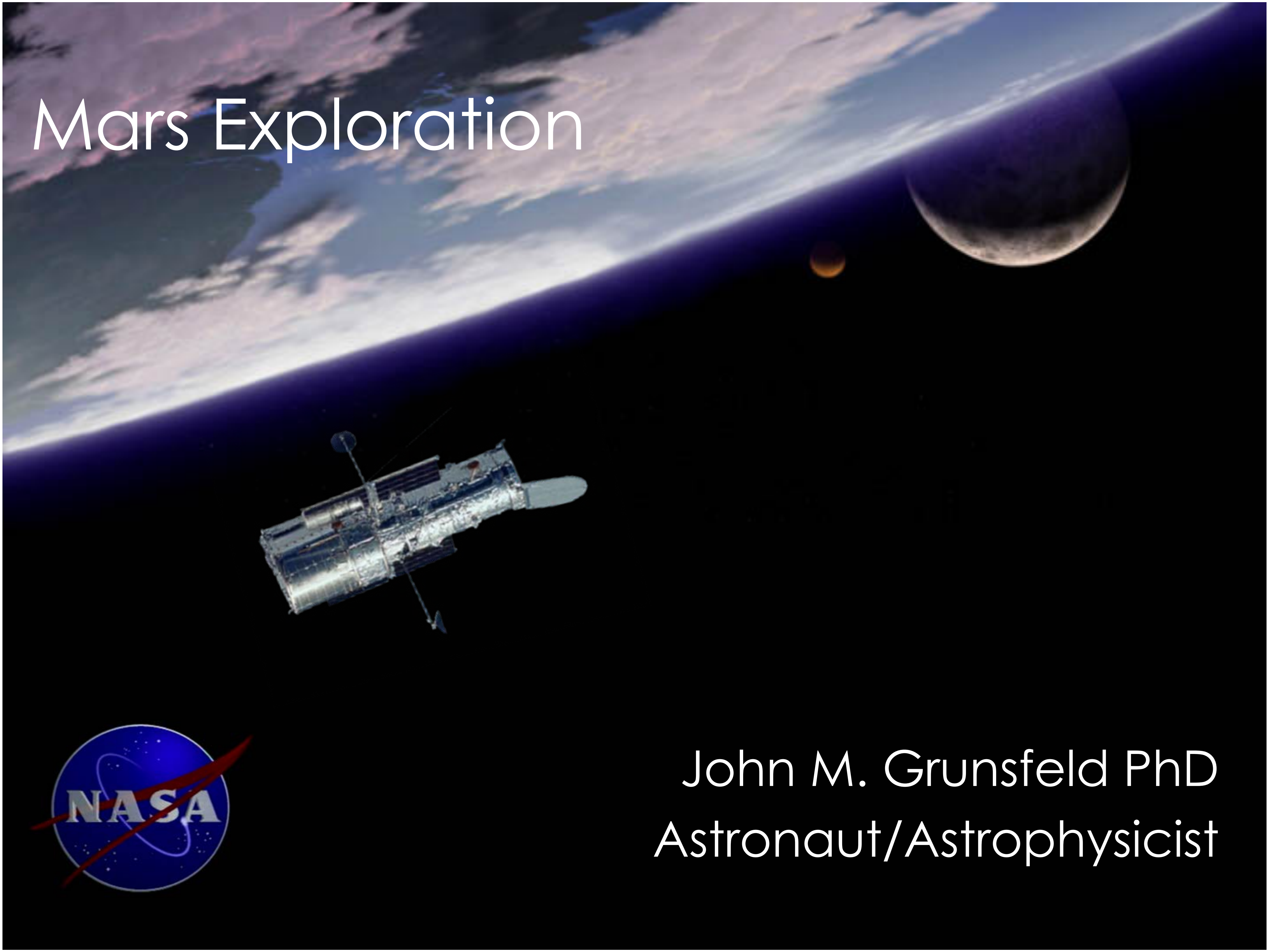

Mars Exploration
NASA
John M. Grunsfeld PhD
Astronaut/Astrophysicist

NASA Mission:

Innovate
Explore
Discover
Inspire

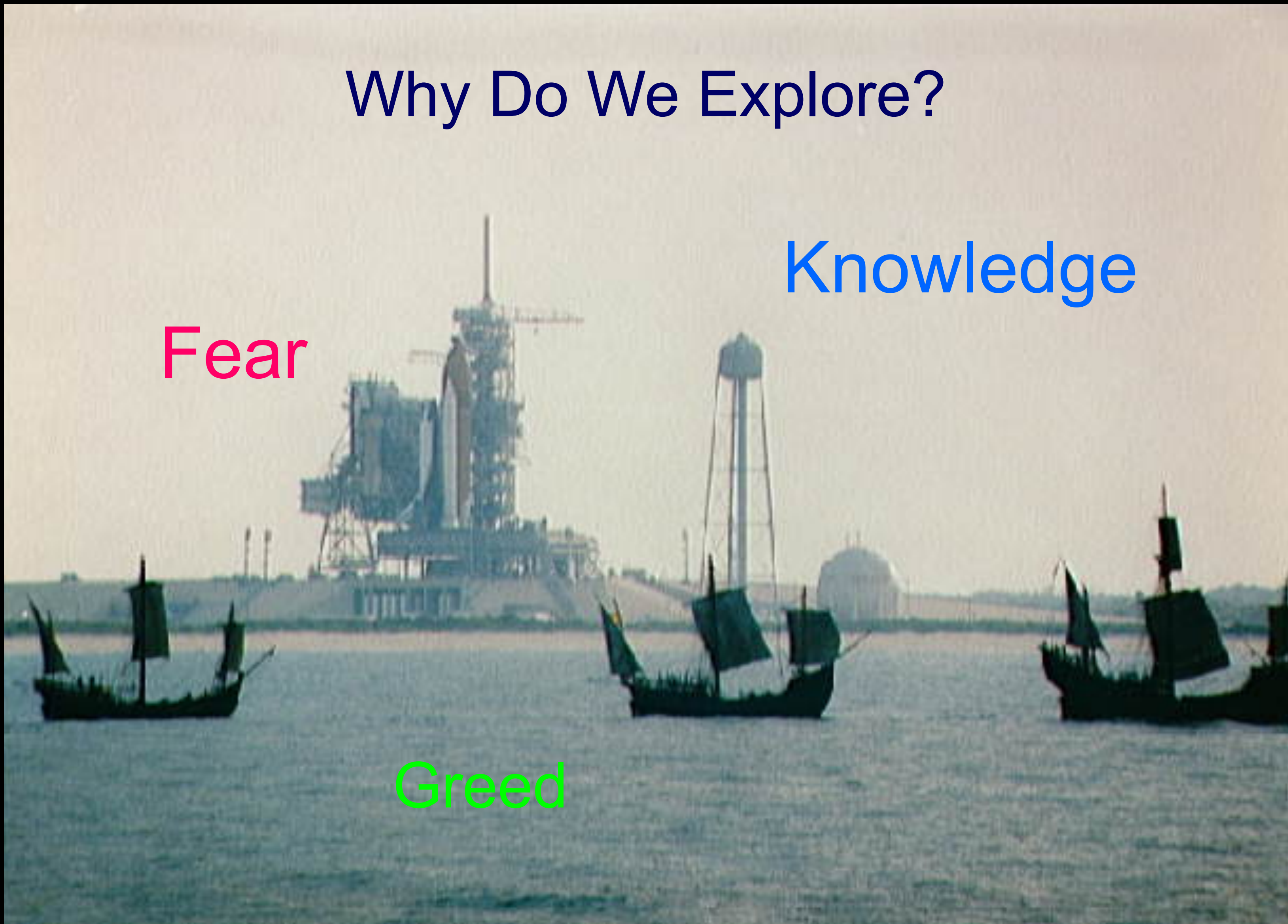
www.nasa.gov

Big Scientific Questions:

Where did we come from?

Where are we going?

Are we alone?

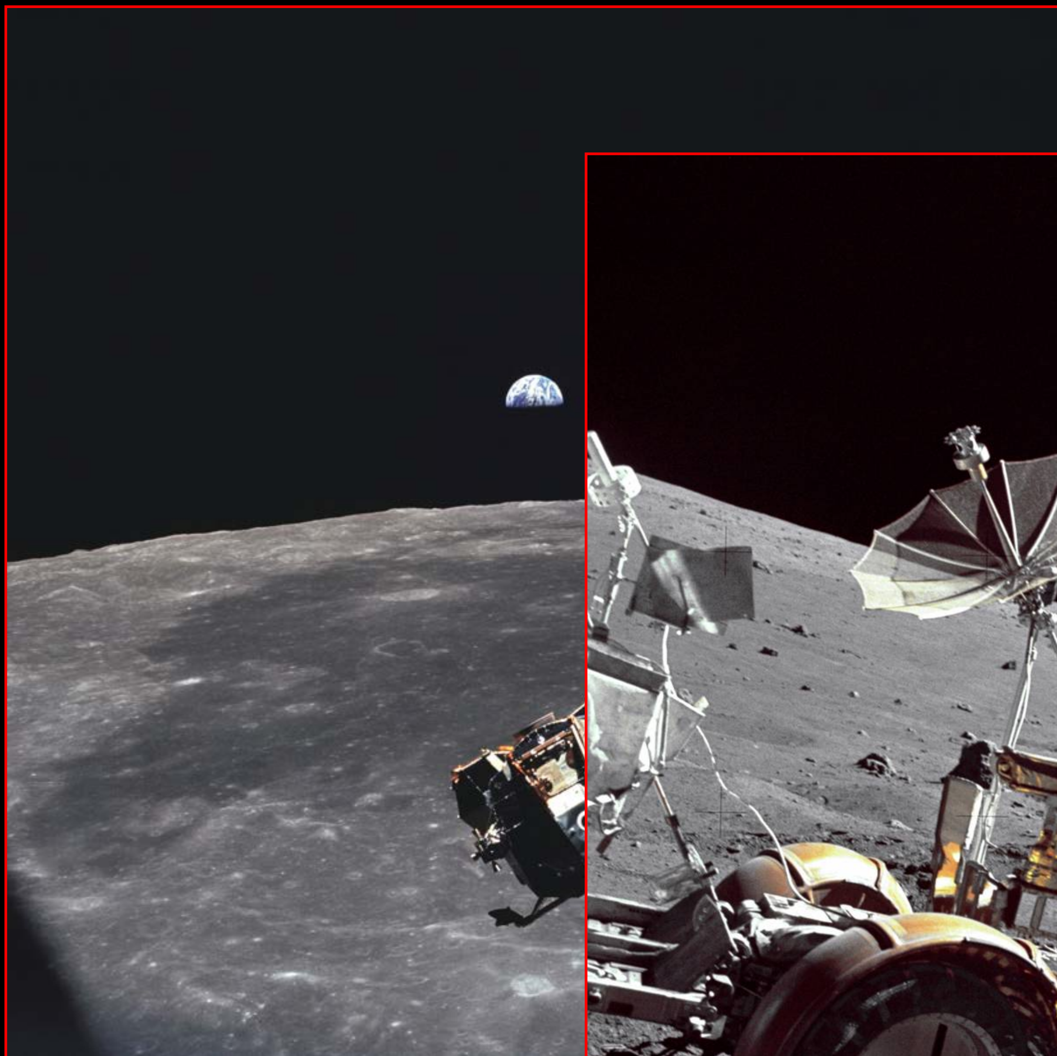

Why Do We Explore?
Knowledge
Fear
Greed

Lunatics

and

Martians

Return to the Moon



On to Mars

Direct Human experience in space fundamentally alters our perspective

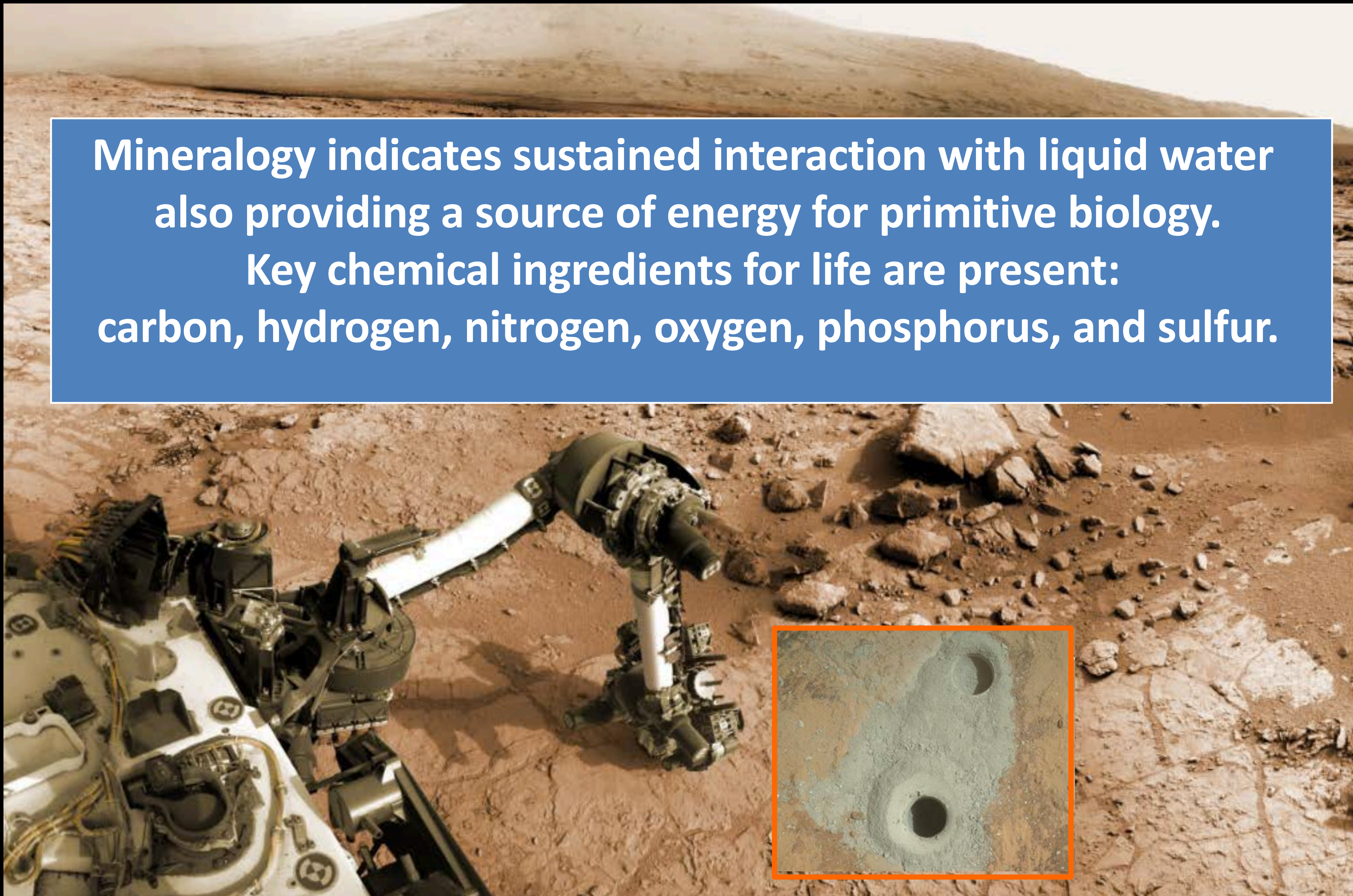
Science allows us to inform, discover, and understand

An Ancient Habitable Environment

Mineralogy indicates sustained interaction with liquid water also providing a source of energy for primitive biology.

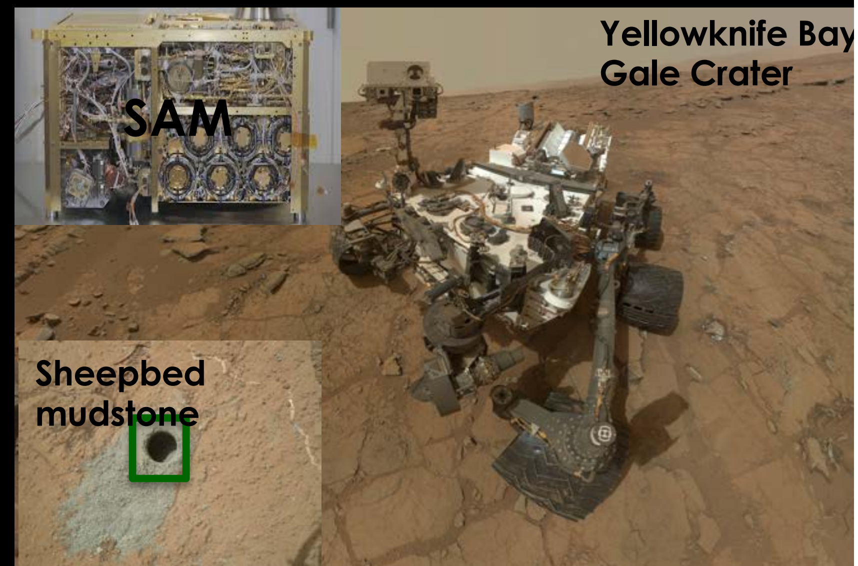
Key chemical ingredients for life are present:

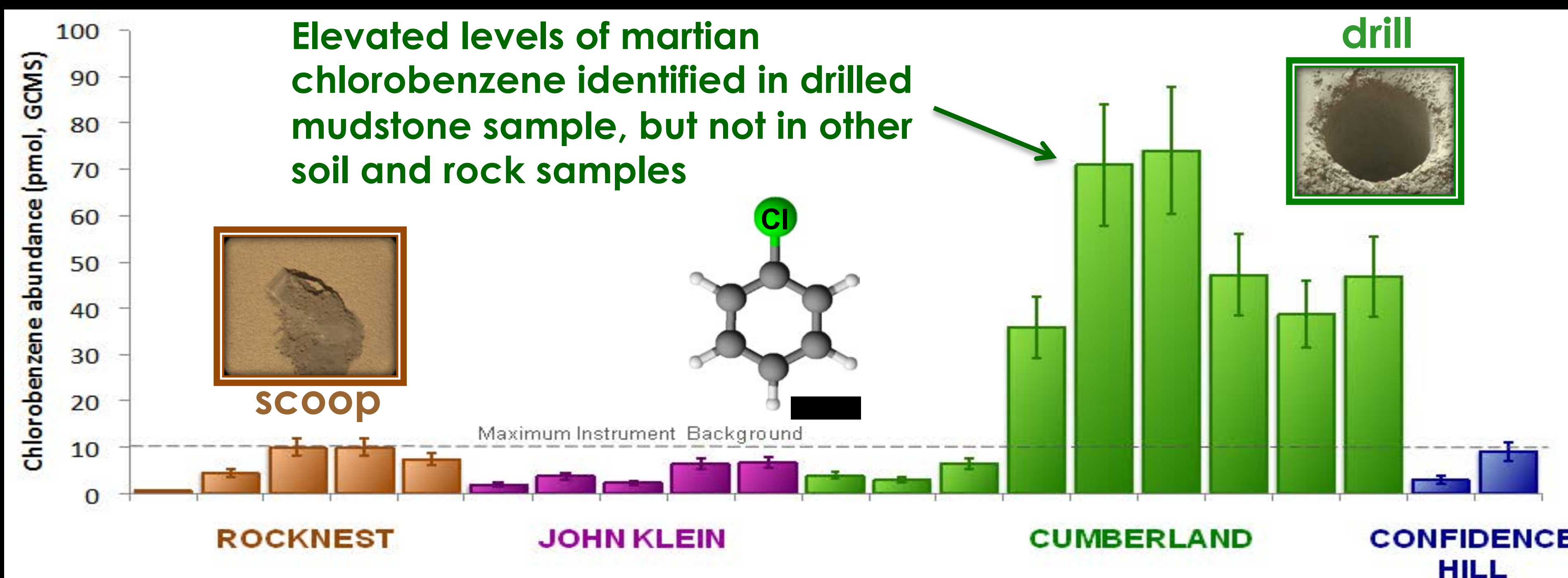
carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur.



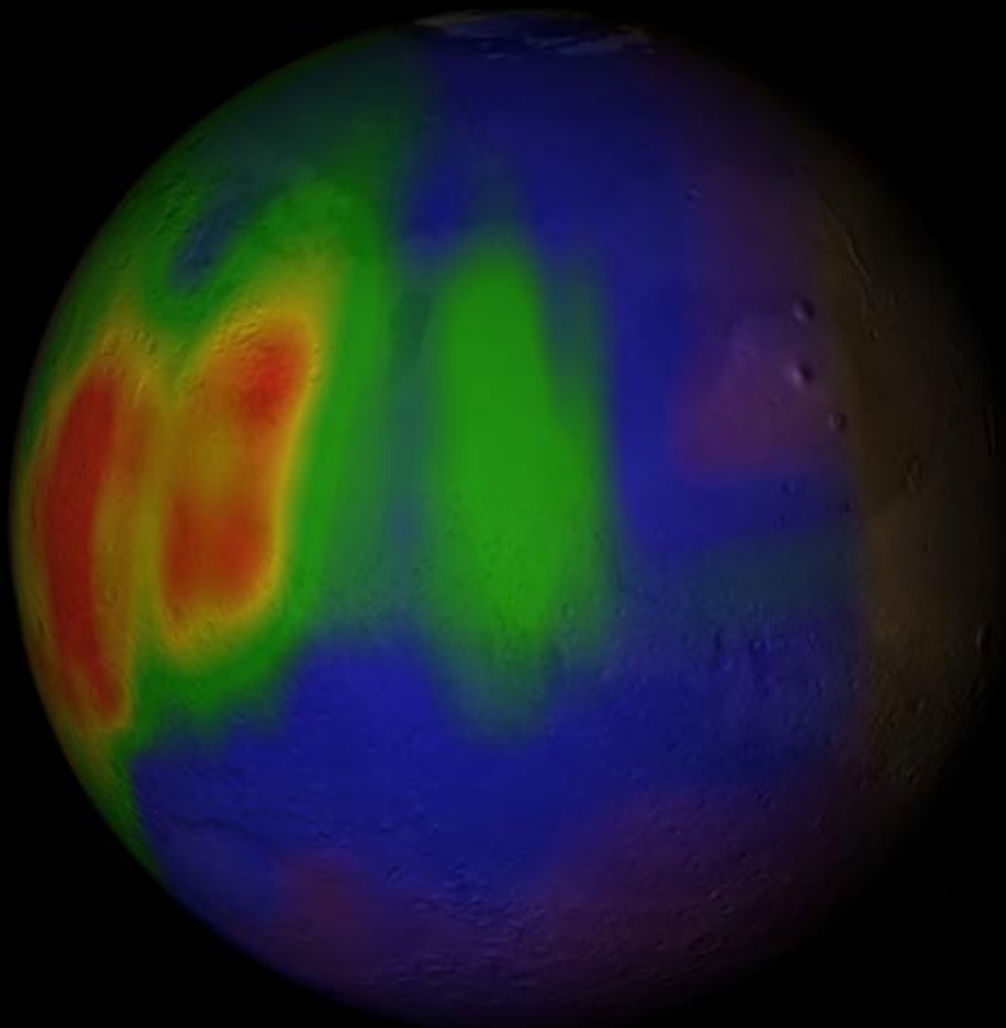
First Detection of Martian Organics by Curiosity

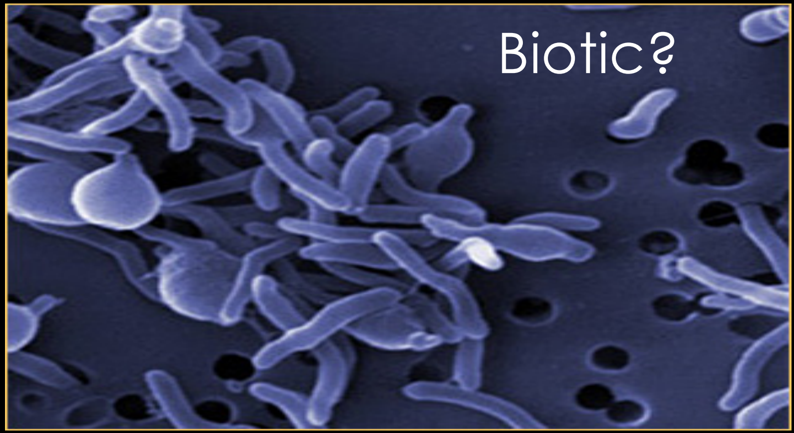
- **The SAM instrument on Curiosity identified elevated levels of chlorobenzene and other chlorinated organics in an ancient lake mudstone collected at Yellowknife Bay**
- **Demonstrates that organics can be preserved on Mars**
- **Results published: Freissinet, C., Glavin, D.P. *et al.* (2015),, *J. Geophys. Res. Planets*, 120, *doi:*[10.1002/2014JE004737](10.1002/2014JE004737).**

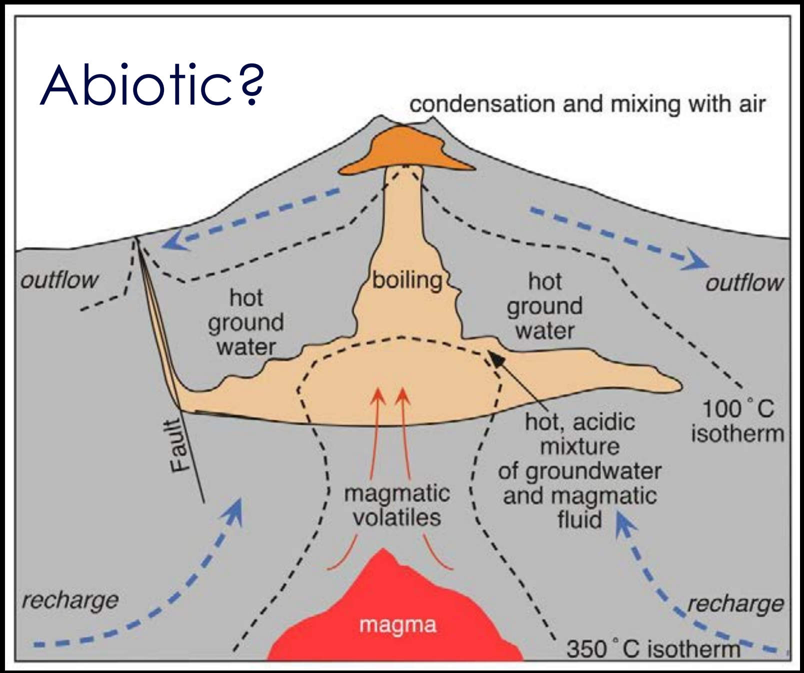


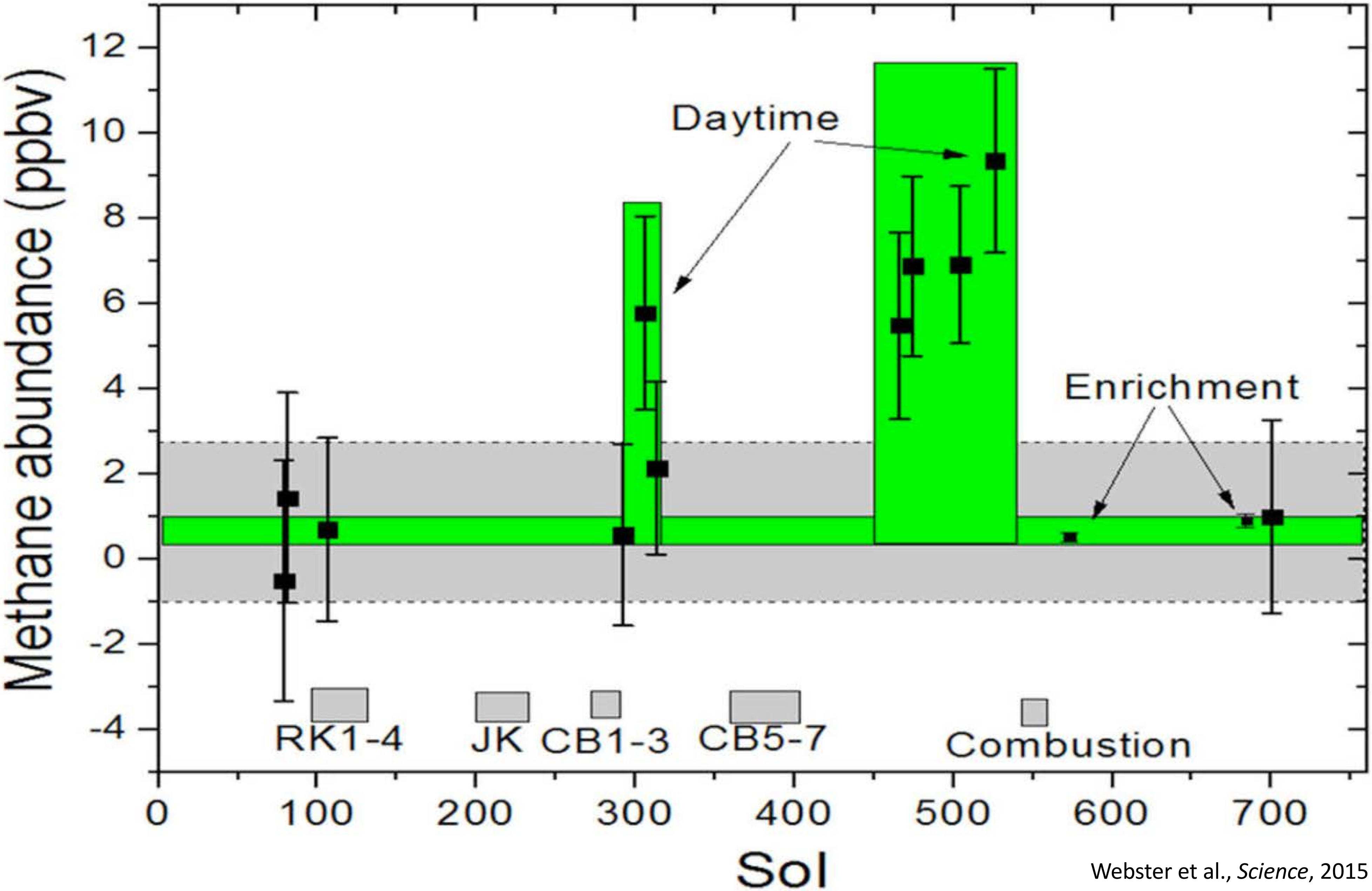


Methane Found on Mars!
Source Indicates an Active Planet









Webster et al., *Science*, 2015

Curiosity measured a background methane abundance of 0.7 ppbv and a ten-fold enhancement that lasted ~ 60 sols

Hot off the Press

Seasonal variations in atmospheric composition as measured in Gale Crater, Mars

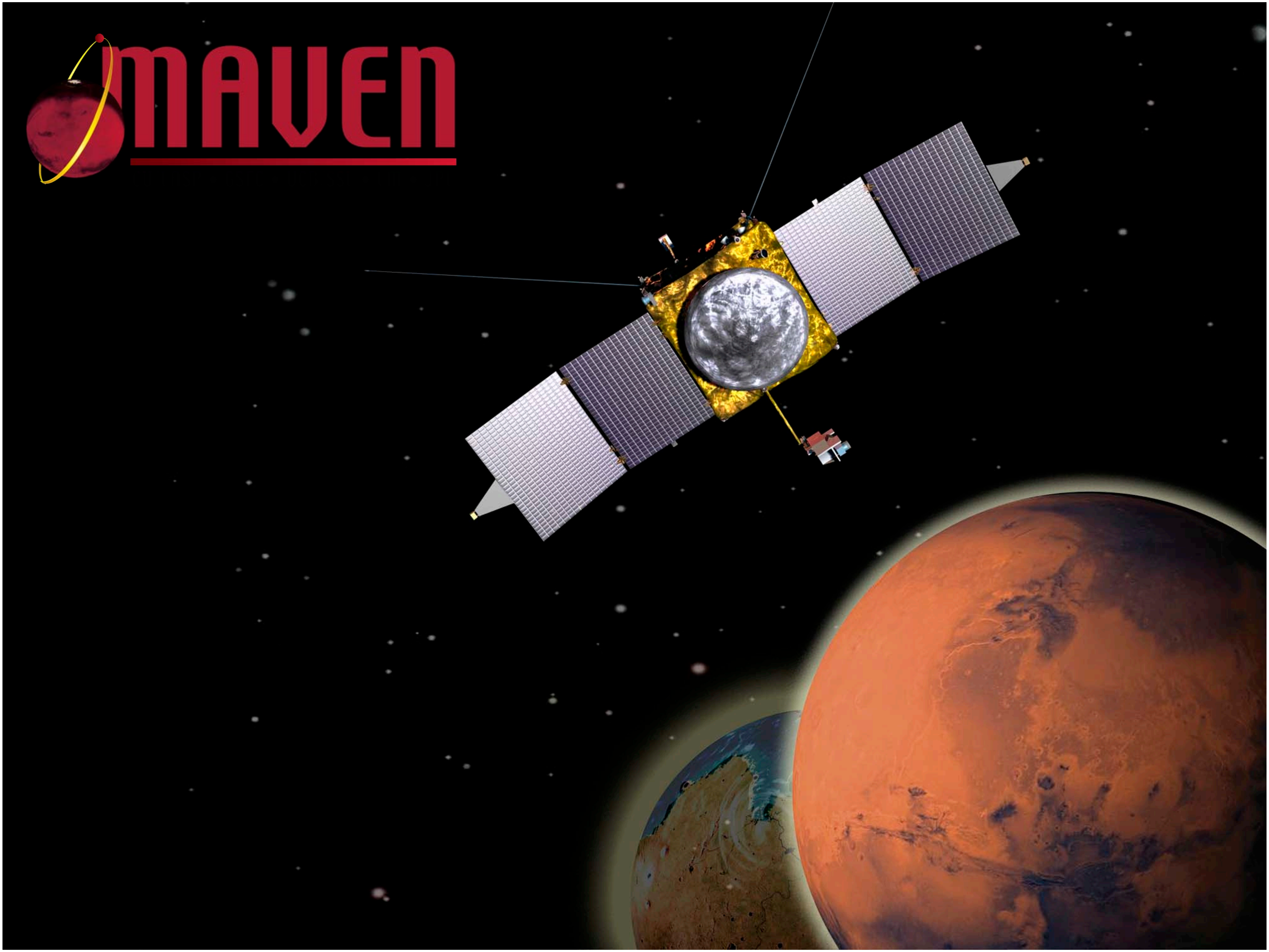
Melissa G. Trainer[1*], Michael H. Wong[2], Timothy H. McConnochie[3], Heather B. Franz[1], Sushil K. Atreya[2], Pamela G. Conrad[4], Franck Lefèvre[5], Paul R. Mahaffy[1], Charles A. Malespin[1], Heidi L. K. Manning[6], Javier Martín-Torres[7,8], Germán M. Martínez[9,2], Christopher P. McKay[10], Rafael Navarro-González[11], Álvaro Vicente-Retortillo[2], Christopher R. Webster[12], María-Paz Zorzano[13, 7]

Key points

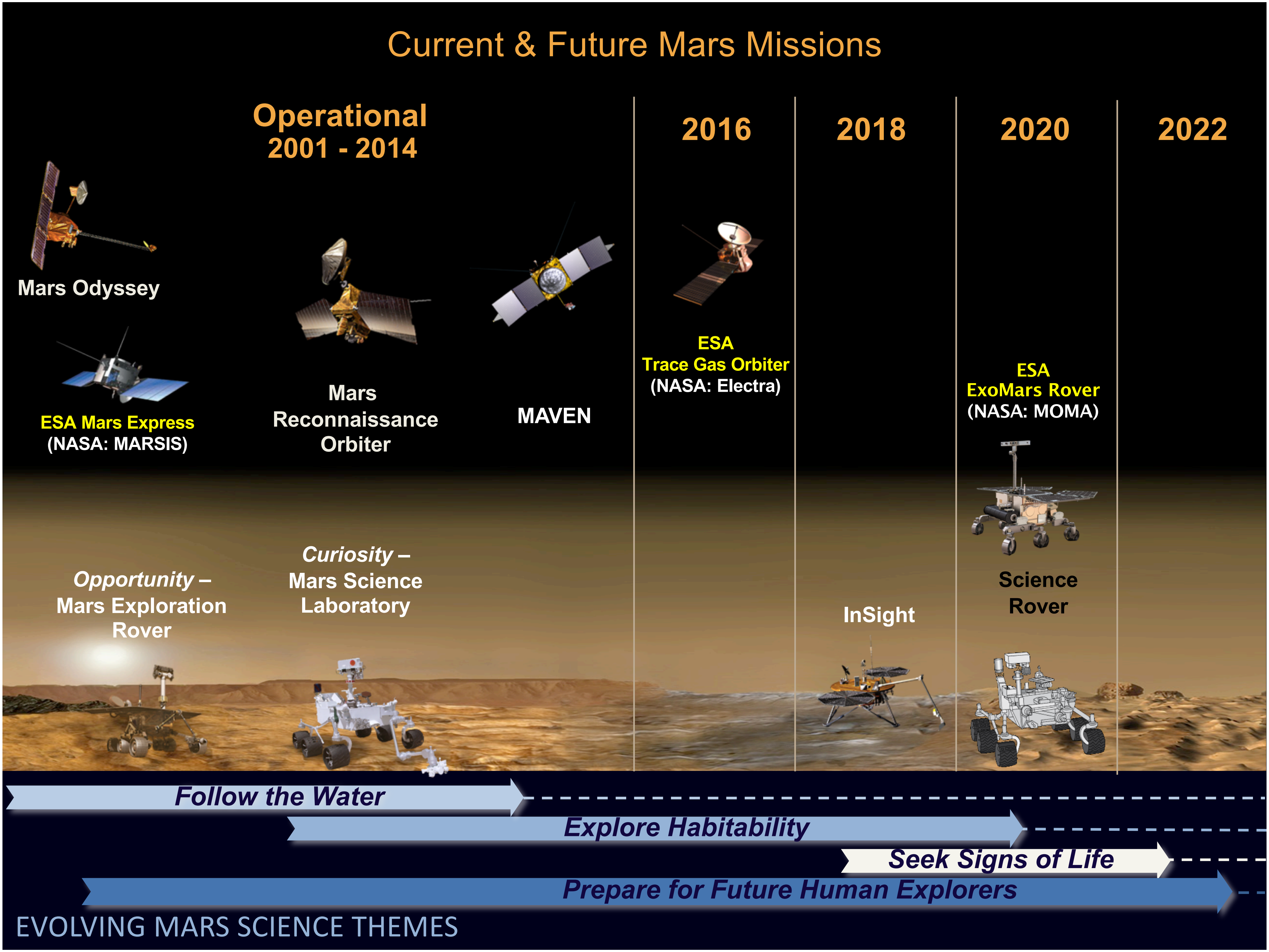
- First multi-year in situ measurements of the major components of the Mars atmosphere have been obtained by the MSL/SAM investigation
- Seasonal variation of CO_2, N_2, and Ar reveal differences in atmospheric transport and mixing timescales.
- Oxygen varies seasonally and interannually, independently from Ar and N_2, on timescales too fast to be explained by known chemistry.

Trainer et al. (2019) JGR in press


Spectral Evidence for Hydrated Salts in Recurring Slope Lineae on Mars.
L. Ojha et al., Nature Geoscience, 28 September, 2015


MAVEN


MAVEN
1



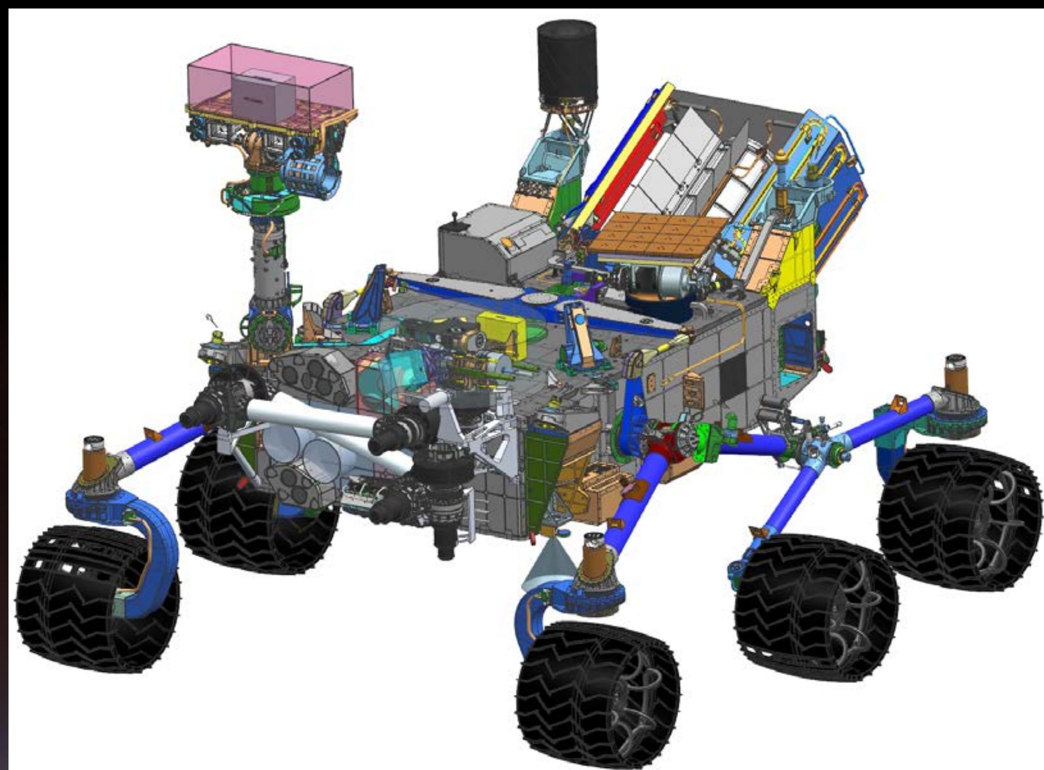
Current & Future Mars Missions
Operational
2001 - 2014
2016
2018
2020
2022
Mars Odyssey
ESA Mars Express
(NASA: MARSIS)
Mars
Reconnaissance
Orbiter
MAVEN
ESA
Trace Gas Orbiter
(NASA: Electra)
ESA
ExoMars Rover
(NASA: MOMA)
Opportunity – Mars Exploration Rover
Curiosity – Mars Science Laboratory
InSight
Science Rover
Follow the Water
Explore Habitability
Seek Signs of Life
Prepare for Future Human Explorers
EVOLVING MARS SCIENCE THEMES

Seeking signs of life: Mars 2020 Rover

<u>**Conduct rigorous *in situ* science**</u>

Geologically diverse site of ancient habitability

Coordinated, nested context and fine-scale measurements



<u>**Enable the future**</u>

Critical ISRU and technology demonstration required for future Mars exploration

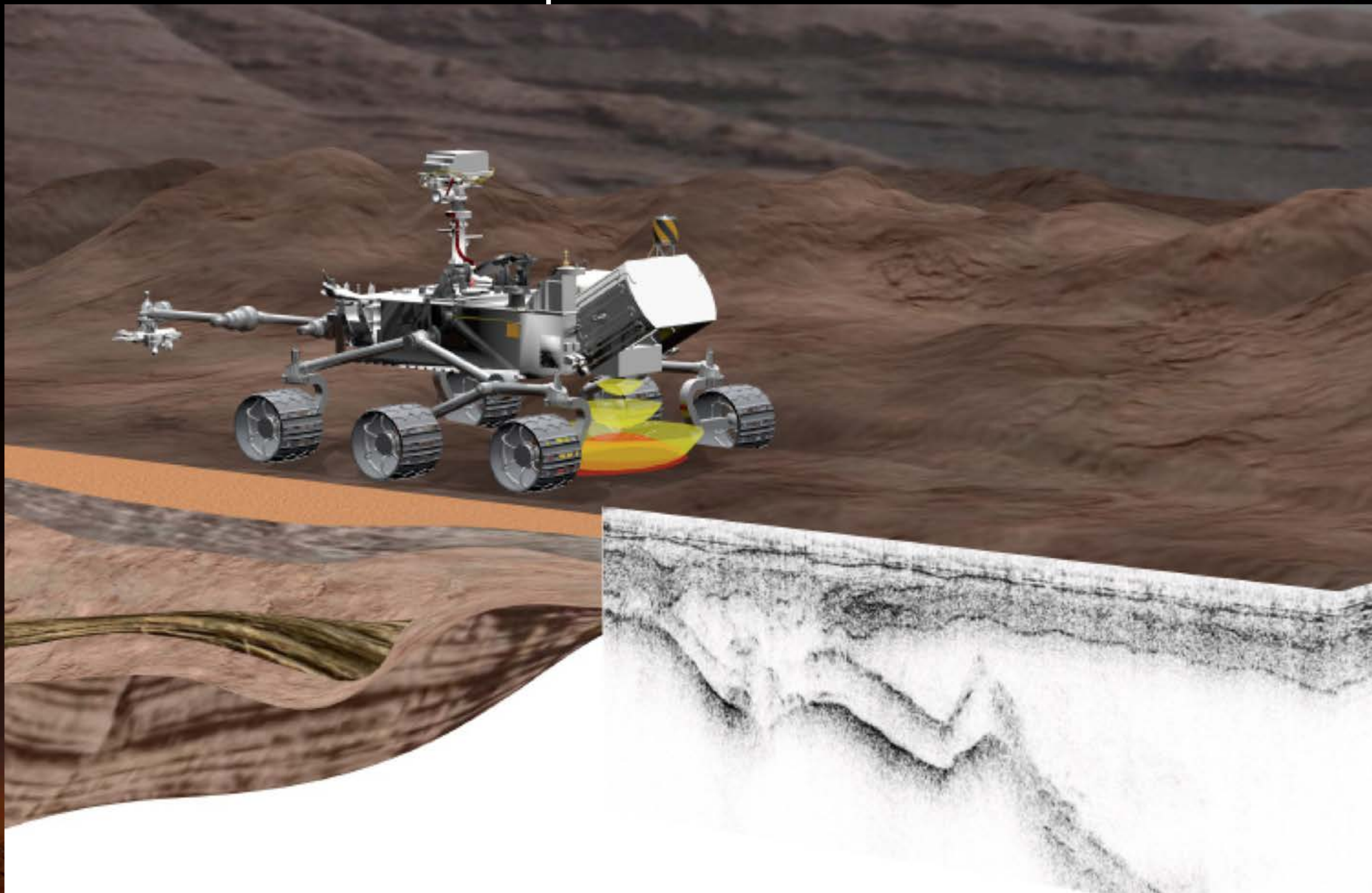
Returnable cache of samples

Mars Oxygen ISRU Experiment

ISRU = *In-situ* Resource Utilization

#JOURNEYTOMARS

Radar Imager for Mars' Subsurface Experiment



#JOURNEYTOMARS

Pat Rawlings

Denali, AK -40^{o}C/0.4 atm

Robots versus Humans
(hint: both)

Human Advantage

- Decision making
- Connection to humans/home
- Feedback and redirection
- Adaptability in real time
- Human intuition/insight
- Intelligent exploration
- Outreach
- Inspiration
- Who is going to repair the robots?
- Tele-robotic control w/minimal latency
- Upgrading
- Repairing
- Survival
- Pattern recognition

Robots versus Humans
(hint: both)

Human Advantage

- Communicate in human language
- Dexterity and adaptable dexterity
- Situational awareness
- Multi-sensor, non-linear, adaptable processing
- Self-healing
- Human anticipation
- Expect the unexpected
- Creativity

Robots versus Humans
(hint: both)

Mars2020 Rover Cost ~$4B
operates for 2 Earth years

Human Crew to Mars (6) ~$150B (random estimate)

Qualified Crew members could do the work of Mars2020 in about 5 days, and analyze the samples on Mars. In 2-years would do 150 times the science.

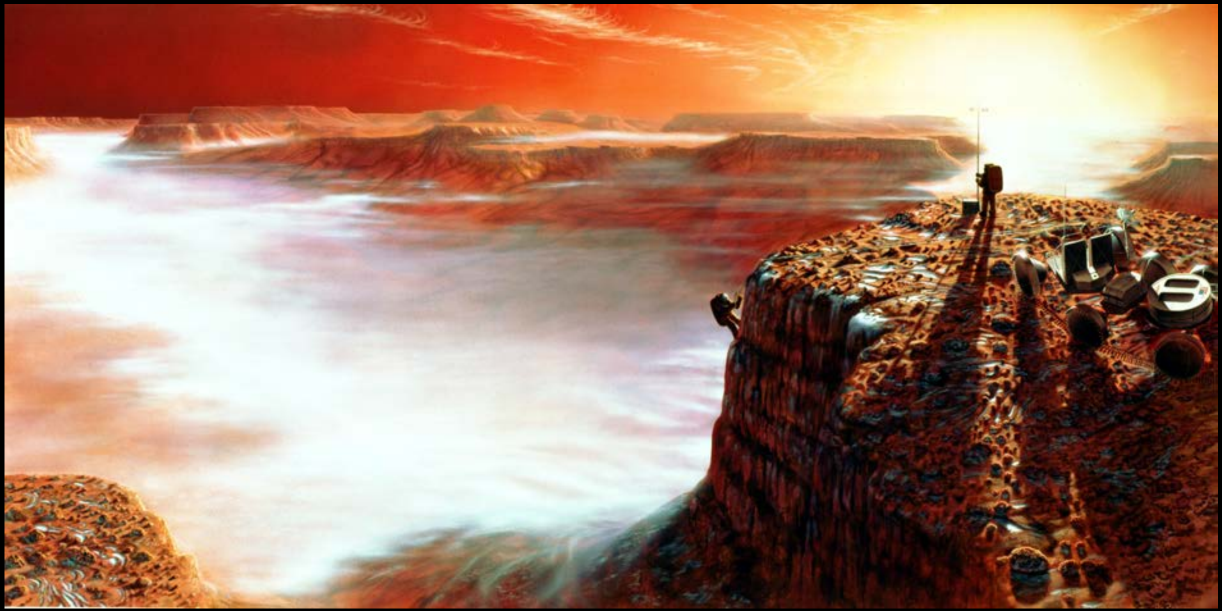
e.g. Humans are 150 times more efficient → Do the science of the rover at ¼ the cost/unit science!

Robots versus Humans (hint: both)

Of course, that doesn't matter if you don't have $150B

We can only send robots today. Even when we do send human explorers the robots will be there too.

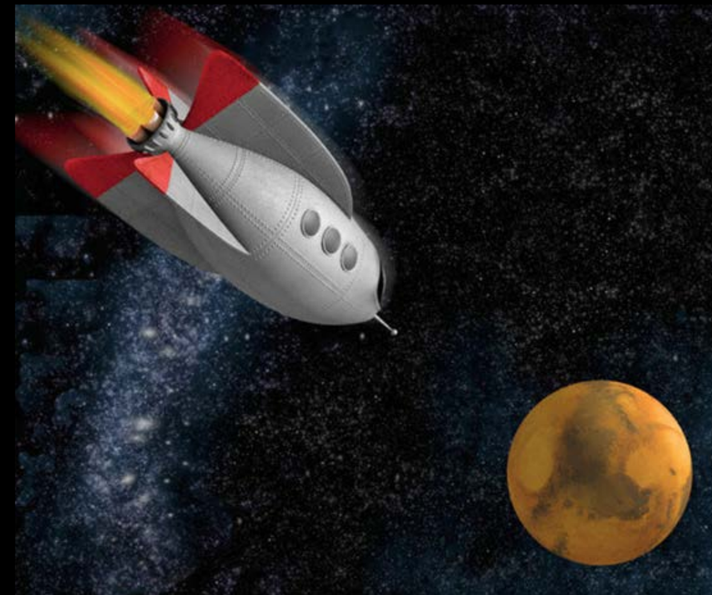
We need the robots for the dull, dangerous, and dirty work.



Pat Rawlings

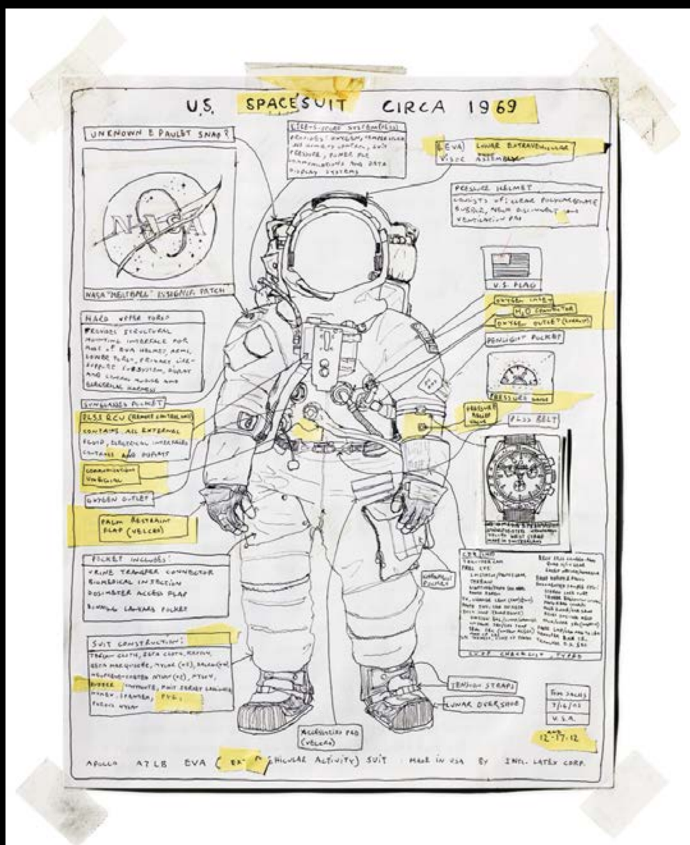
What do we need to do before we can go?

Maintainable ECLSS



Faster Rockets

Spacesuits



Space Nutrition

It's not about the $$$, it is whether we have the will to go…

Consider a conjunction class orbital Mars mission:

Transportation	10 x $350M = $3.5B
Payloads	10 x $1B = $10B
Crew transport	1 x $500M = $0.5B

Total: $14B x 2 = <u>$28B</u>

NASA Spends $4B/year on "exploration"

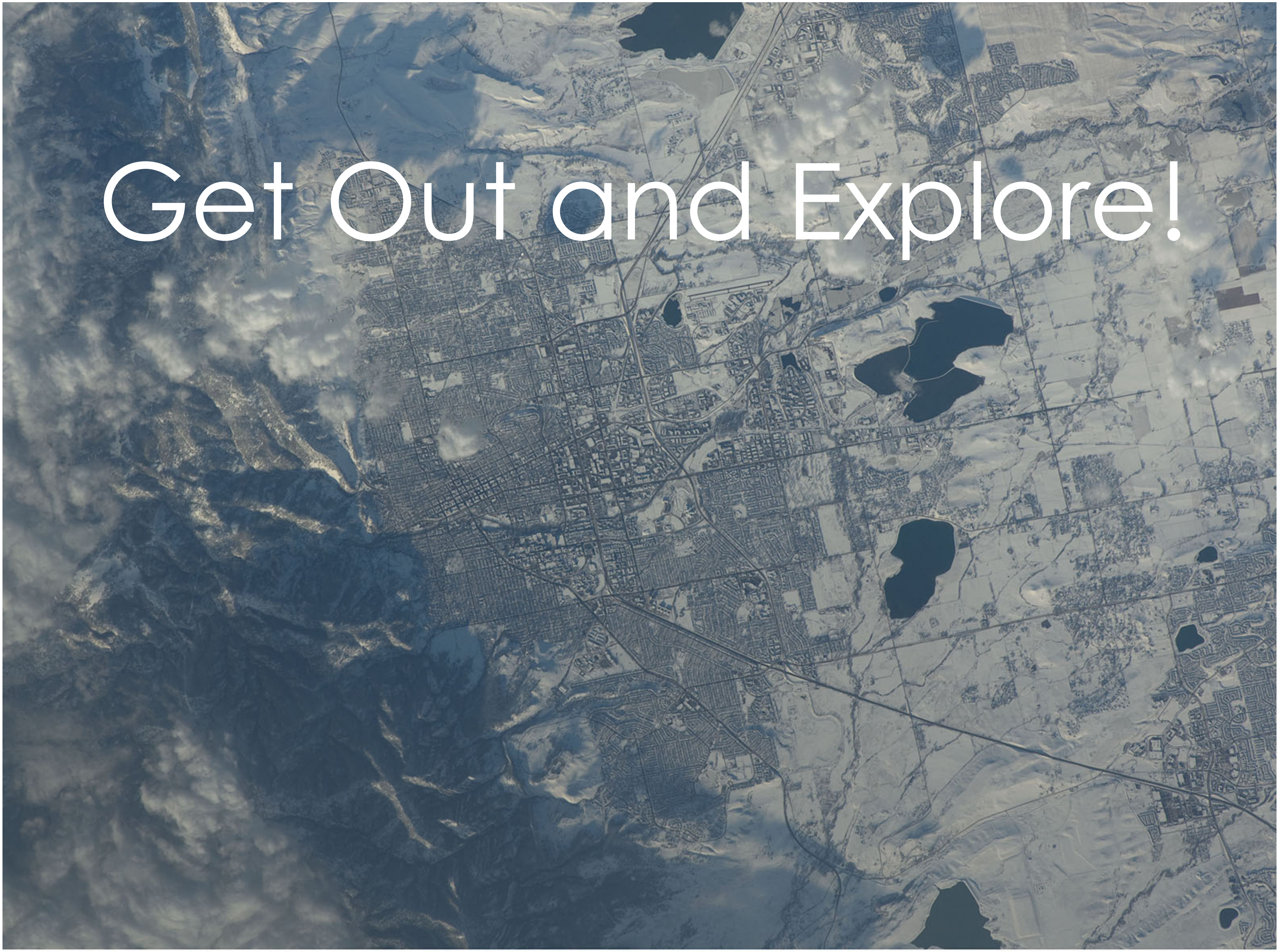
IN 7 YEARS WE COULD FUND A MISSION TO MARS

And have a full backup to fly a second mission 26 months later if all the rockets work!

We are born to explore

2004

imagine the moment...


Get Out and Explore!

www.nasa.gov

Go Buffs!